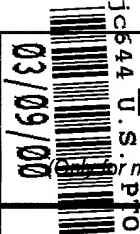


+

 03/09/00 10644 U.S. PTO	<b>UTILITY PATENT APPLICATION TRANSMITTAL</b> <i>(Only for new nonprovisional applications under 37 CFR 1.53(b))</i>		Attorney Docket No. 35.C14341
			First Named Inventor or Application Identifier
			MANABU KATO
			Express Mail Label No.

<b>APPLICATION ELEMENTS</b> See MPEP chapter 600 concerning utility patent application contents.		<b>ADDRESS TO:</b> Assistant Commissioner for Patents Box Patent Application Washington, DC 20231	
1. <input checked="" type="checkbox"/> Fee Transmittal Form <i>(Submit an original, and a duplicate for fee processing)</i>		6. <input type="checkbox"/> Microfiche Computer Program (Appendix)	
2. <input checked="" type="checkbox"/> Specification <span style="float: right;">Total Pages <b>40</b></span>		7. Nucleotide and/or Amino Acid Sequence Submission <i>(if applicable, all necessary)</i>	
3. <input checked="" type="checkbox"/> Drawing(s) (35 USC 113) <span style="float: right;">Total Sheets <b>7</b></span>		a. <input type="checkbox"/> Computer Readable Copy	
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c. <input type="checkbox"/> Copy from a prior application (37 CFR 1.63(d)) <i>(for continuation/divisional with Box 17 completed)</i> <b>[Note Box 5 below]</b>			
i. <input type="checkbox"/> <b>DELETION OF INVENTOR(S)</b> Signed Statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).			
5. <input type="checkbox"/> Incorporation By Reference <i>(useable if Box 4c is checked)</i> The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4c, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.		<b>ACCOMPANYING APPLICATION PARTS</b>	
		8. <input type="checkbox"/> Assignment Papers (cover sheet & document(s))	
		9. <input type="checkbox"/> 37 CFR 3.73(b) Statement <input type="checkbox"/> Power of Attorney <i>(when there is an assignee)</i>	
		10. <input type="checkbox"/> English Translation Document <i>(if applicable)</i>	
		11. <input type="checkbox"/> Information Disclosure Statement (IDS)/PTO-1449 <input type="checkbox"/> Copies of IDS Citations	
		12. <input type="checkbox"/> Preliminary Amendment	
		13. <input checked="" type="checkbox"/> Return Receipt Postcard (MPEP 503) <i>(Should be specifically itemized)</i>	
		14. <input type="checkbox"/> Small Entity <input type="checkbox"/> Statement filed in prior application Statement(s) Status still proper and desired	
		15. <input type="checkbox"/> Certified Copy of Priority Document(s) <i>(if foreign priority is claimed)</i>	
		16. <input type="checkbox"/> Other: _____	

17. If a CONTINUING APPLICATION, check appropriate box and supply the requisite information:

☐ Continuation   
 ☐ Divisional   
 ☐ Continuation-in-part (CIP)   
 of prior application No. \_\_\_\_\_

**18. CORRESPONDENCE ADDRESS**

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CLAIMS	(1) FOR	(2) NUMBER FILED	(3) NUMBER EXTRA	(4) RATE	(5) CALCULATIONS
	TOTAL CLAIMS (37 CFR 1.16(c))	39-20 =	19	X \$ 18.00 =	\$ 342.00
	INDEPENDENT CLAIMS (37 cfr 1.16(b))	4-3 =	1	X \$ 78.00 =	\$ 78.00
	MULTIPLE DEPENDENT CLAIMS (if applicable) (37 CFR 1.16(d))			\$ 260.00 =	\$ 0.00
				BASIC FEE (37 CFR 1.16(a))	\$ 690.00
	Total of above Calculations =				\$1110.00
	Reduction by 50% for filing by small entity (Note 37 CFR 1.9, 1.27, 1.28).				
	TOTAL =				\$1110.00

## 19. Small entity status

- a. ☐ A Small entity statement is enclosed
- b. ☐ A small entity statement was filed in the prior nonprovisional application and such status is still proper and desired.
- c. ☐ Is no longer claimed.

20. ☒ A check in the amount of \$1110.00 to cover the filing fee is enclosed.

21. ☐ A check in the amount of \$\_\_\_\_\_ to cover the recordal fee is enclosed.

22. The Commissioner is hereby authorized to credit overpayments or charge the following fees to Deposit Account No. 06-1205:

- a. ☒ Fees required under 37 CFR 1.16.
- b. ☐ Fees required under 37 CFR 1.17.
- c. ☐ Fees required under 37 CFR 1.18.

## SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT REQUIRED

NAME	T. Tom C. Gellenthien - Reg. No. 39,683
SIGNATURE	<i>Tom Gellenthien</i>
DATE	March 9, 2000

SWOITCG\cmv

MULTIBEAM SCANNING OPTICAL APPARATUS

AND

COLOR IMAGE-FORMING APPARATUS

5 BACKGROUND OF THE INVENTION

Field of the Invention

10 This invention relates to a multibeam scanning optical apparatus and also to a color image-forming apparatus. A multibeam scanning optical apparatus is an apparatus adapted to optically scan the surface of an object by means of a plurality of light beams that are emitted from one or more than one light sources, deflected by an optical deflector and transmitted by way of a scanning optical system having an  $f\theta$  characteristic. A color image-forming apparatus is an apparatus adapted to record image information obtained by scanning the surface of an image carrier by means of deflected light. Such apparatus find applications in the field of laser beam printers (LBPs) and digital copying machines having a feature of carrying out a color electrophotography process.

Related Background Art

25 In conventional scanning optical apparatus to be used for image-forming apparatus such as laser beam printers and digital copying machines, the light beam emitted from a light source and optically modulated according to the image signal applied to it is

periodically deflected by a light deflector typically comprising a rotary polygon mirror and then focussed on the surface of a photosensitive recording medium (photosensitive drum) to produce a spot of light there  
5 by means of a focussing optical system having an  $f\theta$  characteristic, which optical system is then used to scan the surface of the recording medium and record the image on the recording medium.

FIG. 1 of the accompanying drawings schematically  
10 illustrates a principal portion of a known scanning optical apparatus.

Referring to FIG. 1, a divergent light beam emitted from light source 81 is substantially collimated by a collimator lens 82 and restricted for  
15 quantity by a diaphragm 83 before it enters a cylindrical lens 84 that is made to have a predetermined refractive power only in the sub-scanning direction. The substantially collimated light beam entering the cylindrical lens 84 is then made to exit  
20 the lens as a beam substantially collimated in the main-scanning plane, while it is converged in the sub-scanning plane to produce a linear image on the deflection plane (reflection plane) 85a1 of a light deflector 85 comprising a rotary polygon mirror.

25 Then, the light beam deflected and reflected by the deflection plane 85a1 of the light deflector 85 is led to the surface 88 of a photosensitive drum to be

scanned by way of a scanning optical element having an  
f $\theta$  characteristic (f $\theta$  lens) 86 so that the surface 88  
of the photosensitive drum is optically scanned in the  
direction indicated by arrow 88a (main-scanning  
5 direction) to record the scanned image as the light  
deflector 85 is driven to rotate in the sense of arrow  
85a.

In order to accurately control the starting point  
of the operation of drawing the image for the scanning  
10 optical apparatus, the light beam deflected by the  
light deflector 85 is partly taken out and entered to  
beam detector (BD) sensor 92 by way of the scanning  
optical element 86, a beam detector (BD) mirror 95 and  
a slit 91 immediately prior to the start of writing the  
15 image signal. Then, the output signal of the beam  
detector (BD) sensor 92 is used to regulate the timing  
and the spot at which the operation of drawing the  
image on the surface of the photosensitive drum is  
started.

20 In recent years, as a result of technological  
development in the field of image forming apparatus  
involving the use of an electrophotography process  
particularly in terms of high speed and high  
resolution, there is an ever-increasing demand for  
25 multibeam scanning optical apparatus comprising a  
multibeam laser device having a plurality of light  
emitting sections and scanning optical apparatus of the

type employing a plurality of scanning optical apparatus as so many units in order to realize high speed color image formation as shown in FIG. 2 that illustrates a tandem type color image forming apparatus where a plurality of scanning optical apparatus are operated simultaneously for different colors in order to record image information on respective photosensitive drums as well as hybrid type color image forming apparatus realized by combining apparatus of the above identified types. In FIG. 2, reference numerals 111, 112, 113 and 114 denote respective scanning optical apparatus and reference numerals 121, 122, 123 and 124 denote respective photosensitive drums operating as so many image carriers, whereas reference numerals 131, 132, 133 and 134 denote respective developing units and reference numeral 141 denotes a conveyor belt.

Since the manufacturing cost of such scanning optical apparatus is vital, the scanning optical element (f $\theta$  lens) is typically prepared by plastic molding without the process of compensating, if any, the chromatic aberration of magnification.

However, in the case of a multibeam scanning optical apparatus adapted to form a final image by means of light beams of a multibeam laser having a plurality of light emitting sections, the plurality of light beams can show discrepancies in terms of

magnification to consequently degrade the quality of the produced image due to various factors including those listed below:

- (1) variances of the initial wavelengths of a plurality of light beams emitted from the multibeam laser;
- (2) variances of the wavelength of the plurality of light beams caused by mode hopping of the multibeam laser that is attributable to environmental changes; and
- (3) fluctuations in the refractive index of the plastic lens also attributable to environmental changes.

In FIG. 1, there are also shown the image region of the known scanning optical apparatus and the displacements of the focussing positions of the light beams as detected at the start of drawing the image when the wavelength of the light source of laser B (as observed by the laser beam emitted from the light source) is modified relative to the wavelength of the light source of the laser A. Note that, while only the focussing points of laser A and laser B are indicated by A and B respectively in FIG. 1, there are actually more focussing points that are not illustrated in FIG. 1.

In an actual image, the displacements of focussing positions on the surface being scanned due to variations of magnification (wavelength) do not give rise to any jittering along the left edge of the image

but they do along the right edge of the image as shown  
in FIG. 3 to consequently degrade the recorded image.  
This is because the timing and the spot at which the  
operation of drawing the image on the surface of the  
5 photosensitive drum is started are regulated  
(synchronized) at the side of starting the scanning  
operation as pointed out above. More specifically,  
referring to FIG. 1, the detection light beam to be  
detected by the BD sensor 92 of the known scanning  
10 optical apparatus strikes aslant the  $f\theta$  lens 86 shared  
with the light beams for scanning the surface to be  
scanned and, if the wavelength of the laser beam  
emitted from the laser A differs from that of the light  
beam emitted from the laser B, they produce a relative  
15 deviation of the focussing positions equal to that of  
the starting points of scanning the surface to be  
scanned. Thus, the starting points of scanning of the  
light beams can be made to agree with each other by  
detecting a part of each of the light beams and so  
20 controlling the scanning timing of the beam as to  
correct the relative deviation of the focussing  
positions due to the difference of the wavelengths on  
the basis of the signals obtained by detecting the  
laser beams. However, it will be appreciated that, as  
25 a result, a remarkable jittering phenomenon can appear  
at the terminating points of scanning.

A similar problem arises in the scanning optical



apparatus of tandem type color image forming apparatus.  
More specifically, when magnification discrepancies  
arises among a number of scanning optical apparatus, a  
relative deviation of registration occurs over the  
5 range from the center toward the right edge of the  
image as shown in FIG. 4 among different colors to  
consequently degrade the produced image. While FIG. 4  
shows a relative deviation of registration between B  
(black) and C (cyan), a similar deviation can occur  
10 among any different colors.

#### SUMMARY OF THE INVENTION

In view of the above identified circumstances, it  
is therefore the first object of the present invention  
15 to provide a multibeam scanning optical apparatus that  
can effectively reduce jittering that can arise due to  
variations (deviations) of magnification among a  
plurality of light beams attributable to the difference  
of initial wavelength (wavelength deviation) among the  
20 plurality of light beams emitted from so many light  
emitting sections and environmental changes even when a  
molded plastic lens is used without being subjected to  
a process of correcting the chromatic aberration of  
magnification.

25 The second object of the present invention is to  
provide a color image forming apparatus having a simple  
configuration and free from the above pointed out

problem of tandem type color image forming apparatus  
that a relative deviation of registration arises among  
different colors (color deviation) due to the  
difference of initial wavelength among the plurality of  
5 light beams emitted from so many scanning optical  
apparatus light emitting sections and environmental  
changes.

According to the invention, the above first object  
is achieved by providing a multibeam scanning optical  
10 apparatus comprising:

a light source having a plurality of light beam  
emitting sections;

a light deflector for deflecting a plurality of  
light beams emitted respectively from said plurality of  
15 light beam emitting sections of said light source;

a scanning optical system for focussing said  
plurality of light beams deflected by said light  
deflector on a surface to be scanned; and

a photodetector for controlling the timing of the  
20 start of scanning of said plurality of light beams by  
detecting a part of at least one of said plurality of  
light beams deflected by said light deflector as  
detection light beam;

said timing of the start of scanning being so  
25 controlled as to make the centers of the scanning areas  
of said light beams agree with each other on the  
surface to be scanned when said plurality of light

[illegible]

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
0	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100

[illegible][illegible][illegible][illegible][illegible]

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
0	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100

[illegible][illegible]

having light source, a light deflector for deflecting a light beam emitted from said source, a scanning optical system for focussing the light beam deflected by said light deflector on a surface to be scanned and a

5 photodetector for controlling the timing of the start of scanning of said light beam by detecting a part of said light beam deflected by said light deflector as detection light beam, said photodetector and the center of the scanning width in the main-scanning direction on  
10 the surface to be scanned being held optically equivalent; and

a plurality of image carriers arranged respectively on the surfaces to be scanned of said scanning optical apparatus for forming images with  
15 respective different colors.

According to the invention, there is also provided a color image forming apparatus comprising:

a plurality of scanning optical apparatus, each having light source, a light deflector for deflecting a  
20 light beam emitted from said source, a scanning optical system for focussing the light beam deflected by said light deflector on a surface to be scanned, a photodetector for controlling the timing of the start of scanning of said light beam by detecting a part of  
25 said light beam deflected by said light deflector as detection light beam and a detection optical element for converging said detection light beam and leading it

to said photodetector, said detecting optical element having its optical plane arranged orthogonally relative to said detection light beam; and

a plurality of image carriers arranged  
5 respectively on the surfaces to be scanned of said scanning optical apparatus for forming images with respective different colors.

When the plurality of light beams show respective wavelengths that are different from each other in a  
10 multibeam optical apparatus according to the invention, the timing of the start of scanning is so controlled as to make the centers of the scanning areas of said light beams agree with each other on the surface to be scanned simply by controlling the timing of scanning in  
15 the main-scanning direction at or near the center of the scanning width in the main-scanning direction on the surface to be scanned by means of the photodetector (BD) sensor. This means that the photodetector and the center of the scanning width in the main-scanning  
20 direction on the surface to be scanned are held optically equivalent. Similarly, in each of the scanning optical apparatus of a color image forming apparatus according to the invention, the timing of the start of scanning is so controlled as to make the  
25 centers of the scanning areas of said light beams agree with each other on the surface to be scanned simply by controlling the timing of scanning in the main-scanning

direction at or near the center of the scanning width in the main-scanning direction on the surface to be scanned by means of the photodetector (BD) sensor.

5 The photodetector and the center of the scanning width in the main-scanning direction on the surface to be scanned can be held optically equivalent by so arranging the detecting optical element for focussing the detection light beam and leading it to the photodetector (BD) sensor as to have its optical plane  
10 arranged orthogonally relative to said detection light beam. This is because the main light beam of the flux of light striking the center of the scanning width in the main-scanning direction generally agrees with the optical axis of the scanning optical system ( $f\theta$  lens)  
15 and hence this light beam and the light beam entering the photodetector (BD) sensor are made to optically equivalent.

For the purpose of the invention, the expression that "the detecting optical element having its optical  
20 plane arranged orthogonally relative to the detection light beam" means that the main light beam of the flux of light as detected by the photodetector (BD) sensor substantially agrees with the optical axis of the detecting optical element. The expression "as detected  
25 by the photodetector" is used because the light beam entering the photodetector is used for scanning and therefore the main light beam of the flux of light does

not always agree with the optical axis of the detecting optical element. In other words, there exists a state where the main light beam of the flux of light being used for scanning can agree with optical axis of the detecting optical element.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of a principal portion of a known scanning optical apparatus.

FIG. 2 is a schematic illustration of a principal portion of a known tandem type color image forming apparatus.

FIG. 3 is a schematic illustration of a surface being scanned by a known scanning optical apparatus, showing some focussing positions.

FIG. 4 is a schematic illustration of a surface being scanned by a known tandem type color image forming apparatus, showing some focussing positions.

FIG. 5 is a schematic cross sectional view of a principal portion of the first embodiment of multibeam scanning optical apparatus according to the invention taken along the main-scanning direction thereof.

FIG. 6 is a schematic illustration of a surface being scanned by the first embodiment of multibeam scanning optical apparatus, showing some focussing positions.

FIG. 7 is a schematic cross sectional view of a

principal portion of the second embodiment of the invention, which is a color image forming apparatus, taken along the main-scanning direction thereof.

FIG. 8 is a schematic illustration of a surface being scanned by the second embodiment of color image forming apparatus, showing some focussing positions.

FIG. 9 is a schematic cross sectional view of a principal portion of the third embodiment of the invention, which is also a multibeam scanning optical apparatus, taken along the main-scanning direction thereof.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

Now, the present invention will be described in greater detail by referring to the accompanying drawings that illustrate preferred embodiments of the invention.

##### [Embodiment 1]

FIG. 5 is a schematic cross sectional view of a principal portion of the first embodiment of multibeam scanning optical apparatus according to the invention taken along the main-scanning direction thereof.

In FIG. 5, reference numeral 1 denotes a light source comprising a multi-semiconductor laser (multibeam laser) having a plurality of light emitting sections (laser A and laser B in this embodiment) for emitting a plurality of light beams that are optically



modulated independently.

Reference numeral 2 denotes a collimator lens operating as first optical element for collimating the plurality of light beams emitted from the light source

5 1. Reference numeral 3 denotes a diaphragm 3 for restricting the quantity of light passing therethrough. Reference numeral 4 denotes a cylindrical lens (cylinder lens) operating as second optical element and showing refractive power of a predetermined level only  
10 in the sub-scanning direction. It focusses, in the direction of the sub-scanning plane, the plurality of light beams passing through the diaphragm 3 on the deflection plane (reflection plane) 5a of optical deflector 5, which will be described below, as a linear  
15 image.

Reference numeral 5 denotes an optical deflector that may be a rotary polygon mirror driven to rotate at a predetermined rate in the sense indicated by arrow 5a in FIG. 5 by a drive means (not shown) such as an  
20 electric motor.

Reference numeral 6 denotes a scanning optical element operating as third optical element showing a  $f\theta$  characteristic and comprising a refraction optical element 61 and a diffraction optical element 62. The  
25 refraction optical element 61 consists of a single plastic toric lens whose optical power differs between the main-scanning direction and the sub-scanning

direction. The diffraction optical element 62 consists of an oblong plastic diffraction element whose optical power differs between the main-scanning direction and the sub-scanning direction. While the oblong  
5 diffraction element 62 of this embodiment is made of plastic and formed by injection molding, it may alternatively be a diffraction grating formed as replica on a glass substrate.

In this embodiment, the toric lens 61 is arranged  
10 at the side of the polygon mirror 5 relative to the middle point of the axis of rotation of the polygon mirror 5 and the surface to be scanned 8, whereas the diffraction optical element 62 is arranged at the side of the surface to be scanned relative to the middle  
15 point. Each of the above listed optical elements has optical power that differs between the main-scanning direction and the sub-scanning direction and operates to focus the deflected light beam from the polygon mirror 5 on the surface to be scanned and correct the  
20 inclination of the deflection plane of the polygon mirror. When the multibeam scanning optical apparatus is applied to an electronic photograph printer, the surface to be scanned 8 refers to the surface of the photosensitive drum of the printer. Therefore,  
25 reference numeral 8 refers to the surface of a photosensitive drum hereinafter.

Reference numeral 7 denotes a synchronism

detecting optical element comprising an anamorphic lens  
made of plastic and showing optical power that differs  
between the main-scanning direction and the sub-  
scanning direction. In this embodiment, the surfaces  
5 of the anamorphic lens 7 is arranged substantially  
orthogonally relative to the plurality of light beams  
from the polygon mirror 5 (synchronism detection light  
beams) 73 for controlling the timing of scanning the  
surface of the photosensitive drum 8 in the main-  
10 scanning direction (synchronizing timing) and adapted  
to focus the synchronism detection light beam 73 near  
slit 71 both in the main-scanning plane and the sub-  
scanning plane. Reference numeral 75 denotes a mirror  
(to be referred to as "BD mirror" hereinafter) for  
15 reflecting the synchronism detection light beams 73 to  
BD sensor 72, which will be described hereinafter, in  
order to regulate the timing of scanning the surface of  
the photosensitive drum 8 in the main-scanning  
direction. Reference numeral 71 denotes a slit  
20 arranged at a position equivalent to the surface of the  
photosensitive drum 8. Reference numeral 74 denotes a  
beam detector lens (BD lens) operating as focussing  
lens for making the BD mirror 75 and the BD sensor 72  
show a conjugated relationship and correcting the  
25 inclination of the BD mirror 75. Reference numeral 72  
denotes a synchronism detection means comprising the BD  
sensor (photosensor). The synchronism detection means

72 of this embodiment is used to control the timing of scanning of each of the plurality of light beams emitted from the plurality of light emitting sections in the main-scanning direction at or near the center of the scanning width on the surface of the photosensitive drum 8. In other words, if the plurality of light beams have respective wavelengths that are different from each other in this embodiment, the timing of starting a scanning operation of each light beam is so controlled that the centers of the scanning areas of the plurality of light beams agree with each other on the surface to be scanned.

In this embodiment, a pair of divergent light beams (only one of them is shown in FIG. 5) optically modulated and emitted from the multi-semiconductor laser 1 as a function of image information applied to it are substantially collimated by the collimator lens 2 and restricted by the diaphragm 3 for the quantity of light before entering the cylindrical lens 4. The two substantially collimated light beams entering the cylindrical lens 4 then leave the lens without being modified in the main-scanning plane but converged in the sub-scanning plane to produce respective focussed linear images (running along main-scanning direction) on the deflection plane 5a1 of the optical deflector (polygon mirror) 5. The two light beams deflected by the deflection plane 5a1 of the optical deflector 5 are

then focussed as so many spots of light on the surface of the photosensitive drum 8 by way of the toric lens 61 and the refraction optical element 62 so that they scan the surface of the photosensitive drum 8 at a constant rate in the direction (main-scanning direction) as indicated by arrow 8a as the optical deflector 5 is rotated in the sense of arrow 5a. As a result, an image is recorded on the surface of the photosensitive drum 8, which is a recording medium.

At the same time, the two synchronism detection light beams 73 reflected and deflected by the polygon mirror 5 of this embodiment are led to the BD sensor 72 by way of the synchronism detecting optical element 7, the BD mirror 75, the slit 71 and the BD lens 74.

Then, the two BD signals (synchronizing signals) for the main-scanning direction obtained by detecting the output signal of the BD sensor 72 are used to control the timing of scanning (synchronizing timing) in the main-scanning direction at or near the center of the scanning width in the main-scanning direction on the surface of the photosensitive drum 8.

As pointed out above, the surfaces of the single anamorphic lens 7 made of a plastic material and formed by injection molding is arranged substantially orthogonally relative to the synchronism detection light beams 73 in this embodiment. As a result, if, for instance, the wavelength of the light source of the

laser B is shifted relative to the laser A of the multi-semiconductor laser 1 as shown in FIG. 5, the synchronism detection timing (write synchronizing signal) will not be shifted in the main-scanning direction. Note that only the focussed positions of the light beams from the lasers A and B are shown in FIG. 5.

On the other hand, because the timing of scanning is controlled in the main-scanning direction at or near the center of the scanning width in the main-scanning direction on the surface of the photosensitive drum 8, if the wavelength of the light source of the laser B is shifted relative to the laser A, the positions (focussed positions) of the light beams on the surface of the photosensitive drum 8 agree with each other only on the optical axis of the scanning optical element 6 and the magnification of the scanning optical element shows variations that are symmetrical relative to the optical axis in any other positions. Variations of the refractive index of the scanning optical element 6 due to environmental changes also show similar results.

Thus, in this embodiment, the synchronism detection timing does not shift regardless of variations in the wavelength and those in the refractive index due to environmental changes so that the focussing positions of the image area are made to vary symmetrically relative to the optical axis of the

scanning optical element 6 as shown in FIG. 6. As a result, the variations in the magnification can be allocated to the starting side and the terminating side of image drawing to consequently reduce the extent of jittering to about a half of that of known comparable apparatus.

Therefore with the embodiment where the timing of scanning is controlled in the main-scanning direction at or near the center of the scanning width in the main-scanning direction on the surface of the photosensitive drum 8 and the surfaces of the single anamorphic lens 7 are arranged substantially orthogonally relative to the synchronism detection light beams 73, the jittering phenomenon of the multibeam scanning optical apparatus attributable to variations in the wavelength (initial wavelength) and those in the magnification due to environmental changes can be effectively suppressed even an inexpensive plastic lens formed by injection molding and not corrected for chromatic aberration of magnification is used for the scanning optical element.

Note that the scanning optical element of this embodiment comprises a refraction optical element and a diffraction optical element, the advantages of the first embodiment can be realized by using a scanning optical element comprising only a refraction optical element.

[Embodiment 2]

FIG. 7 is a schematic cross sectional view of a principal portion of the second embodiment of multibeam scanning optical apparatus according to the invention taken along the main-scanning direction thereof.

In FIG. 7, reference numerals 11, 12, 13 and 14 denote respective scanning optical apparatus and reference numerals 21, 22, 23 and 24 denote respective photosensitive drums operating as so many image carriers, whereas reference numerals 31, 32, 33 and 34 denote respective developing units and reference numeral 41 denotes a conveyor belt.

This embodiment of color image forming apparatus comprises a total of four scanning optical apparatus (11, 12, 13, 14) arranged for the four colors of C (cyan), M (magenta), Y (yellow) and B (black) and is adapted to record respective image signals (image information) on the corresponding photosensitive drums 21, 22, 23 and 24 in parallel and carry out a color image printing operation at high speed.

As pointed out above, the color image forming apparatus of this embodiment is adapted to form latent images on the corresponding surfaces of the respective photosensitive drums 21, 22, 23 and 24 by means of respective light beams emitted from the four scanning optical apparatus 11, 12, 13 and 14 according to respective modulation signals. More specifically,



latent images of C (cyan), M (magenta), Y (yellow) and B (black) are formed on the corresponding surfaces of the respective photosensitive drums 21, 22, 23 and 24 and then transferred on a recording medium in a  
5 multiplexing fashion to produce a single full color image.

Thus, a color image can be printed at high speed as if a monochromatic image. However, since the four colors do not share a single scanning optical element  
10 in this embodiment, they can show variations in terms of scanning position (registration) to consequently produce a relative deviation of registration among different colors and degrade the produced image.

To avoid this problem, in this embodiment of  
15 tandem type color image forming apparatus comprising a plurality of scanning optical apparatus, the timing of scanning of each of the scanning optical apparatus is controlled on the surface of the corresponding photosensitive drum at or near the center of the  
20 scanning width in the main-scanning direction in a manner as described above by referring to the first embodiment. In other words, the photodetector (BD) sensor and the center of the scanning width in the  
25 main-scanning direction on the surface to be scanned are optically held equivalent. To realize this, the surfaces of the synchronism detecting optical element (anamorphic lens) made of a plastic material and formed

by molding as a single piece are arranged substrantally orthogonally relative to the synchronism detection light beam in each of the scanning optical apparatus.

As a result, as described above by referring to the first embodiment, the timing of synchronism detection is not shifted if the wavelengths of the light sources of the four scanning optical apparatus are varied from each other. Similarly, the timing of synchronism detection is not shifted if the refractive index of any of the synchronism detecting optical elements is shifted due to environmental changes.

On the other hand, because the timing of scanning is controlled in the main-scanning direction at or near the center of the scanning width in the main-scanning direction on the surface of each of the photosensitive drums, if the wavelength of the light source of any of the four scanning optical apparatus is shifted relative to the others, the positions (focussed positions) of the light beams on the surface of the photosensitive drum agree with each other only on the optical axis of the scanning optical element and the magnification of the scanning optical element shows variations that are symmetrical relative to the optical axis at any other positions. Variations of the refractive index of the scanning optical element due to environmental changes also shows similar results.

Thus, in this embodiment, the synchronism

detection timing does not shift regardless of variations in the wavelength and those in the refractive index due to environmental changes so that the focussing positions of the image area are made to vary symmetrically relative to the optical axis of the scanning optical element as shown in FIG. 8. As a result, the variations in the magnification can be allocated to the starting side and the terminating side of image drawing to consequently reduce the extent of relative deviation of registration among different colors to about a half of that of known comparable apparatus. Note that while FIG. 8 shows color deviation between B (black) and C (cyan), similar results are obtained for other colors.

Therefore with the embodiment of scanning optical apparatus used for a tandem type color image forming apparatus where the timing of scanning is controlled in the main-scanning direction at or near the center of the scanning width in the main-scanning direction on the surface of the photosensitive drum and the surfaces of the single anamorphic lens are arranged substantially orthogonally relative to the synchronism detection light beams in each of the scanning optical apparatus, the extent of relative deviation of registration among different colors attributable to variations in the wavelength and those in the magnification due to environmental changes can be

effectively suppressed even an inexpensive plastic lens formed by injection molding and not corrected for chromatic aberration of magnification is used for the scanning optical element.

5           Note that the scanning optical apparatus of this embodiment of color image forming apparatus may be replaced by the multibeam scanning optical apparatus as described above by referring to the first embodiment. Then, the obtained color image forming apparatus can be  
10           operated for an enhanced degree of high speed operation and high definition.

[Embodiment 3]

FIG. 9 is a schematic cross sectional view of a principal portion of the third embodiment of the  
15           invention, which is also a multibeam scanning optical apparatus, taken along the main-scanning direction thereof. In FIG. 9, the components same as those of FIG. 5 are denoted respectively by the same reference symbols.

20           This embodiment differs from the first embodiment only in that the synchronism detecting optical element is formed integrally with the refraction optical element of the scanning optical element by injection molding using a plastic material. Otherwise, this  
25           embodiment is substantially identical with the first embodiment in terms of configuration and optical effect. Thus, this embodiment operates like the first

embodiment.

Referring to FIG. 9, reference numeral 17 denotes the integral type plastic optical element formed by injection molding and operating as synchronism  
5 detecting optical element which is an anamorphic lens and also as refraction optical element which is a toric lens. With this arrangement, any spatial interference of the synchronism detecting optical element and the refraction optical element is eliminated to make it  
10 possible to detect the scanning position at a position close to the image area and reduce the jittering phenomenon.

Note that, while the synchronism detecting optical element and the refraction optical element are  
15 integrally formed in this embodiment, the synchronism detecting optical element and the second optical element which is the cylindrical lens may alternatively formed as integral components by injection molding, using plastic as raw material. Still alternatively,  
20 the synchronism detecting optical element, the refraction optical element and the cylindrical lens may be integrally formed by injection molding, using plastic as raw material. This embodiment may be applied to a color image forming apparatus as described  
25 above by referring to the second embodiment.

WHAT IS CLAIMED IS:

1. A multibeam scanning optical apparatus  
comprising:

5 a light source having a plurality of light beam  
emitting sections;

a light deflector for deflecting a plurality of  
light beams emitted respectively from said plurality of  
light beam emitting sections of said light source;

10 a scanning optical system for focussing said  
plurality of light beams deflected by said light  
deflector on a surface to be scanned; and

a photodetector for controlling the timing of the  
start of scanning of said plurality of light beams by  
detecting a part of at least one of said plurality of  
15 light beams deflected by said light deflector as  
detection light beam;

said timing of the start of scanning being so  
controlled as to make the centers of the scanning areas  
of said light beams agree with each other on the  
20 surface to be scanned when said plurality of light  
beams have respective wavelengths that are different  
from each other.

2. A multibeam scanning optical apparatus  
25 according to claim 1, further comprising:

a detection optical element for converging said  
detection light beam and leading it to said

photodetector;

said detection optical element having its optical plane arranged orthogonally relative to the detection light beam.

5

3. A multibeam scanning optical apparatus according to claim 2, wherein

said detection optical element comprises an anamorphic lens.

10

4. A multibeam scanning optical apparatus according to claim 2, wherein

said detection optical element is made of a plastic material.

15

5. A multibeam scanning optical apparatus according to claim 2, wherein

said scanning optical system comprises a refraction optical element and a diffraction optical element.

20

6. A multibeam scanning optical apparatus according to claim 5, wherein

said refraction optical element and said diffraction optical element are made of a plastic material.

25

7. A multibeam scanning optical apparatus  
according to claim 6, wherein

5 said detection optical element and said refraction  
optical element are integrally formed by using a  
plastic material.

8. A multibeam scanning optical apparatus  
according to claim 2, further comprising:

10 an incident optical system for leading a plurality  
of light beams emitted from said light source to said  
optical deflector.

9. A multibeam scanning optical apparatus  
according to claim 8, wherein

15 said incident optical system comprises a first  
lens for collimating each of said plurality of light  
beams emitted from said light source and a second lens  
for focussing each of said plurality of collimated  
light beams on the deflection plane of the optical  
20 deflector as a linear image extending in the main-  
scanning direction.

10. A multibeam scanning optical apparatus  
according to claim 9, wherein

25 said detection optical element and said second  
lens are integrally formed by using a plastic material.



11. A multibeam scanning optical apparatus  
according to claim 1, wherein

said photodetector detects part of each of a  
plurality of light beams deflected by said optical  
5 deflector and controls the timing of the start of  
scanning of each of said plurality of light beams.

12. A multibeam scanning optical apparatus  
comprising:

10 a light source having a plurality of light beam  
emitting sections;

a light deflector for deflecting a plurality of  
light beams emitted respectively from said plurality of  
light beam emitting sections of said light source;

15 a scanning optical system for focussing said  
plurality of light beams deflected by said light  
deflector on a surface to be scanned;

a photodetector for controlling the timing of the  
start of scanning of said plurality of light beams by  
20 detecting a part of at least one of said plurality of  
light beams deflected by said light deflector as  
detection light beam; and

a detection optical element for converging said  
detection light beam and leading it to said  
25 photodetector;

said detection optical element having its optical  
plane arranged orthogonally relative to said detection

light beam.

13. A multibeam scanning optical apparatus  
according to claim 12, wherein

5       said detection optical element comprises an  
anamorphic lens.

14. A multibeam scanning optical apparatus  
according to claim 12, wherein

10       said detection optical element is made of a  
plastic material.

15. A multibeam scanning optical apparatus  
according to claim 12, wherein

15       said scanning optical system comprises a  
refraction optical element and a diffraction optical  
element.

16. A multibeam scanning optical apparatus  
20       according to claim 15, wherein

      said refraction optical element and said  
diffraction optical element are made of a plastic  
material.

25       17. A multibeam scanning optical apparatus  
according to claim 16, wherein

      said detection optical element and said refraction

optical element are integrally formed by using a plastic material.

18. A multibeam scanning optical apparatus  
5 according to claim 12, further comprising:  
an incident optical system for leading a plurality of light beams emitted from said light source to said optical deflector.

10 19. A color image forming apparatus comprising:  
a plurality of scanning optical apparatus, each having a light source, a light deflector for deflecting a light beam emitted from said source, a scanning optical system for focussing the light beam deflected  
15 by said light deflector on a surface to be scanned and a photodetector for controlling the timing of the start of scanning of said light beam by detecting a part of said light beam deflected by said light deflector as detection light beam, said photodetector and the center  
20 of the scanning width in the main-scanning direction on the surface to be scanned being held optically equivalent; and

a plurality of image carriers arranged respectively on the surfaces to be scanned of said  
25 scanning optical apparatus for forming images with respective different colors.

5           a detection optical element for converging said  
detection light beam and leading it to said  
photodetector;

21. A color image forming apparatus according to claim 20, wherein

22. A color image forming apparatus according to claim 20, wherein

23. A color image forming apparatus according to  
25 claim 20, wherein

said scanning optical system of each of said scanning optical apparatus comprises a refraction



collimating the light beam emitted from said light source and a second lens for focussing the collimated light beam on the deflection plane of the optical deflector as a linear image extending in the main-  
5 scanning direction.

28. A color image forming apparatus according to claim 27, wherein

10 said detection optical element and said second lens of each of said scanning optical apparatus are integrally formed by using a plastic material.

29. A color image forming apparatus according to claim 19, wherein

15 said light source of each of said scanning optical apparatus comprises a plurality of light emitting sections for emitting a plurality of light beams modulated independently relative to each other.

20 30. A color image forming apparatus comprising:  
a plurality of scanning optical apparatus, each having a light source, a light deflector for deflecting a light beam emitted from said source, a scanning optical system for focussing the light beam deflected  
25 by said light deflector on a surface to be scanned, a photodetector for controlling the timing of the start of scanning of said light beam by detecting a part of

said light beam deflected by said light deflector as  
detection light beam and a detection optical element  
for converging said detection light beam and leading it  
to said photodetector, said detecting optical element  
5 having its optical plane arranged orthogonally relative  
to said detection light beam; and

a plurality of image carriers arranged  
respectively on the surfaces to be scanned of said  
scanning optical apparatus for forming images with  
10 respective different colors.

31. A color image forming apparatus according to  
claim 30, wherein

said detection optical element of each of said  
15 scanning optical apparatus comprises an anamorphic  
lens.

32. A color image forming apparatus according to  
claim 30, wherein

20 said detection optical element of each of said  
scanning optical apparatus is made of a plastic  
material.

33. A color image forming apparatus according to  
25 claim 30, wherein

said scanning optical system of each of said  
scanning optical apparatus comprises a refraction

optical element and a diffraction optical element.

34. A color image forming apparatus according to claim 33, wherein

5        said refraction optical element and said diffraction optical element of each of said scanning optical apparatus are made of a plastic material.

35. A color image forming apparatus according to claim 34, wherein

10        said detection optical element and said refraction optical element of each of said scanning optical apparatus are integrally formed by using a plastic material.

15        36. A color image forming apparatus according to claim 30, wherein

      each of said scanning optical apparatus further comprises:

20        an incident optical system for leading the light beam emitted from said light source to said optical deflector.

37. A color image forming apparatus according to claim 36, wherein

25        said incident optical system of each of said scanning optical apparatus comprises a first lens for

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collimating the light beam emitted from said light  
source and a second lens for focussing the collimated  
light beam on the deflection plane of the optical  
deflector as a linear image extending in the main-  
5 scanning direction.

38. A color image forming apparatus according to  
claim 37, wherein

10 said detection optical element and said second  
lens of each of said scanning optical apparatus are  
integrally formed by using a plastic material.

39. A color image forming apparatus according to  
claim 30, wherein

15 said light source of each of said scanning optical  
apparatus comprises a plurality of light emitting  
sections for emitting a plurality of light beams  
modulated independently relative to each other.

A multibeam scanning optical apparatus comprises a light source, an incident optical system, an optical deflector, a scanning optical system, a detection optical element, and a photodetector. A plurality of light beams modulated in accordance with information signals are emitted from the light source and lead to the optical deflector, typically a rotary polygon mirror, by way of the incident optical system, typically a collimator lens and a cylindrical lens. The light beams deflected by the optical deflector are then focussed on a surface to be scanned, typically a photosensitive drum, by way of the scanning optical system having an  $f\theta$  characteristic. Part of the deflected light beams are lead to the photodetector by way of the detection optical system in order to control the timing of the start of scanning so that the centers of the scanning areas of the plurality of light beams agree with each other on the surface to be scanned. In case of a color image forming apparatus comprising a plurality of scanning optical apparatus, the above control scheme can be applied even when the scanning optical apparatus have a single beam light source.

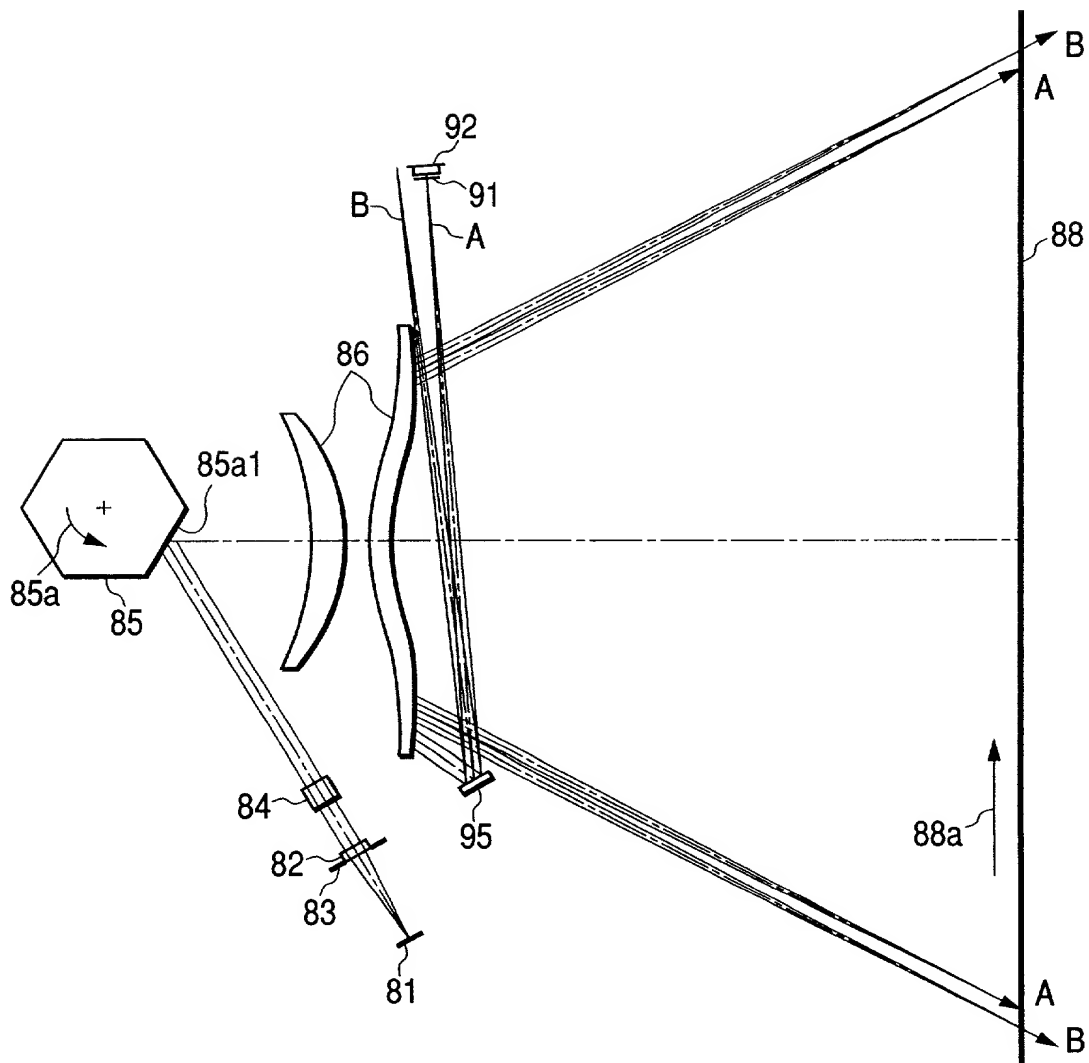
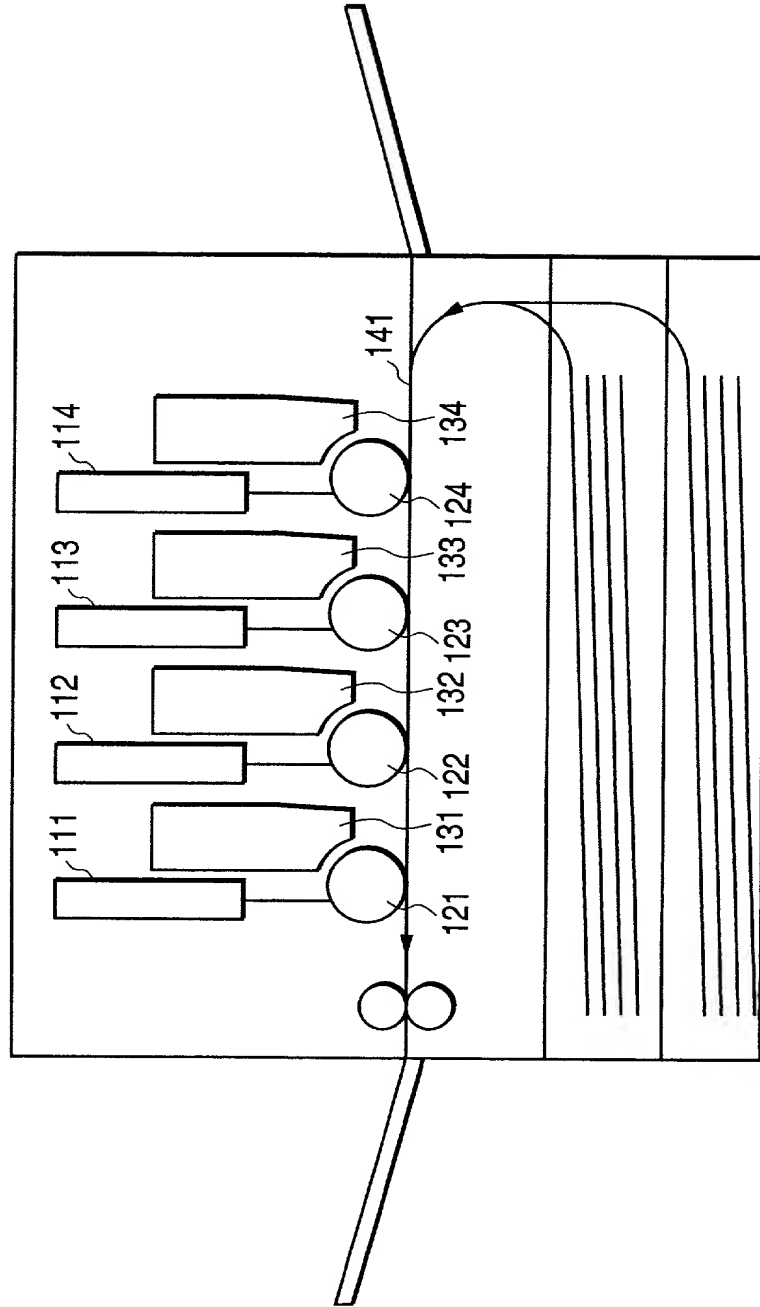
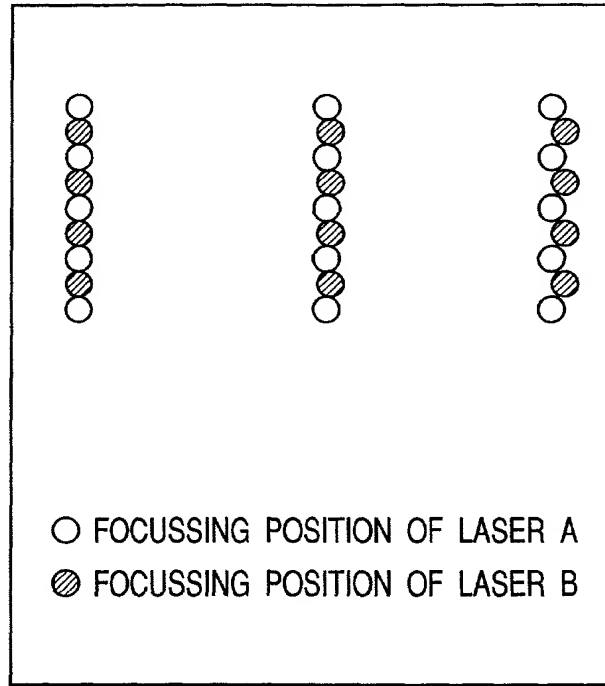
*FIG. 1 PRIOR ART*

FIG. 2 PRIOR ART



**FIG. 3 PRIOR ART**



**FIG. 4 PRIOR ART**

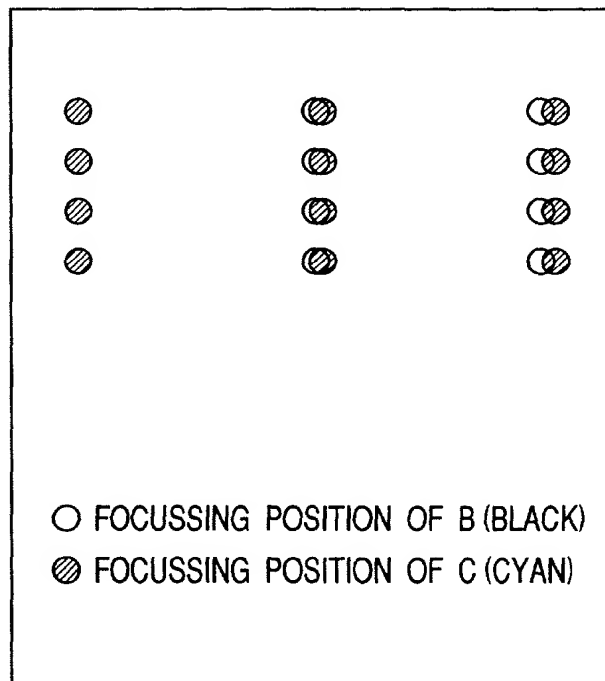
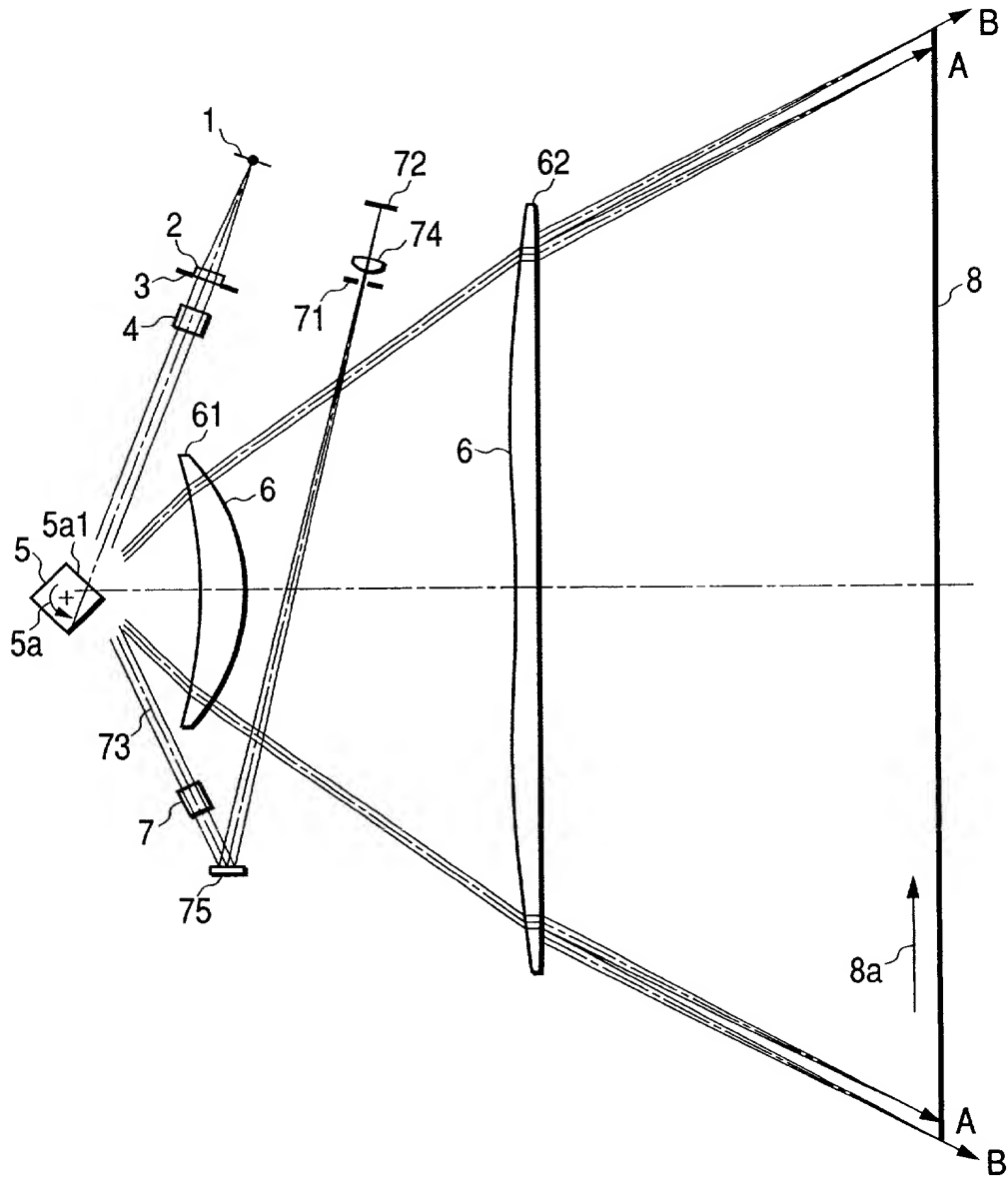
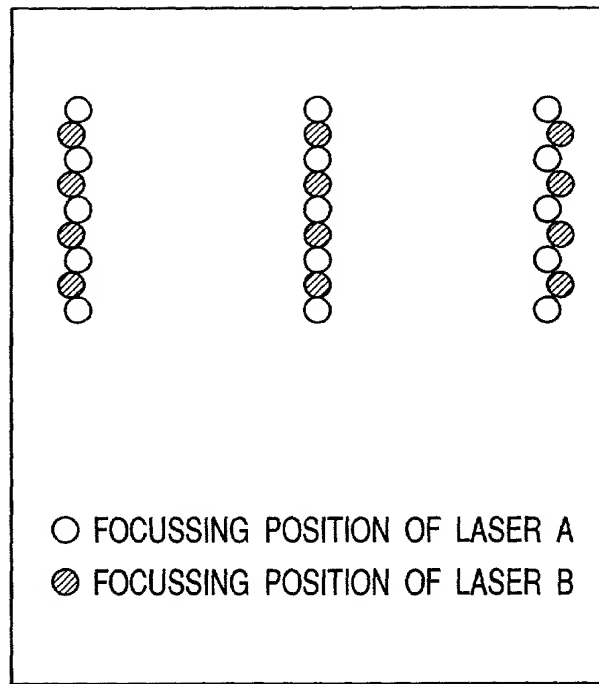


FIG. 5



*FIG. 6*



*FIG. 8*

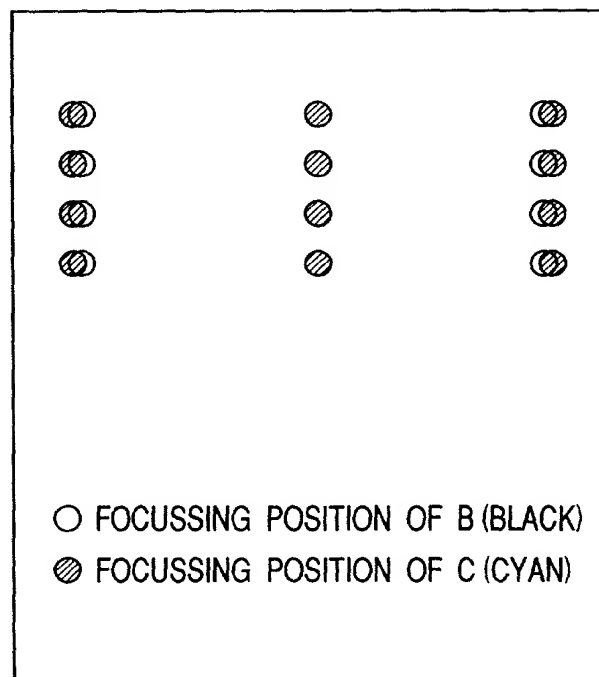


FIG. 7

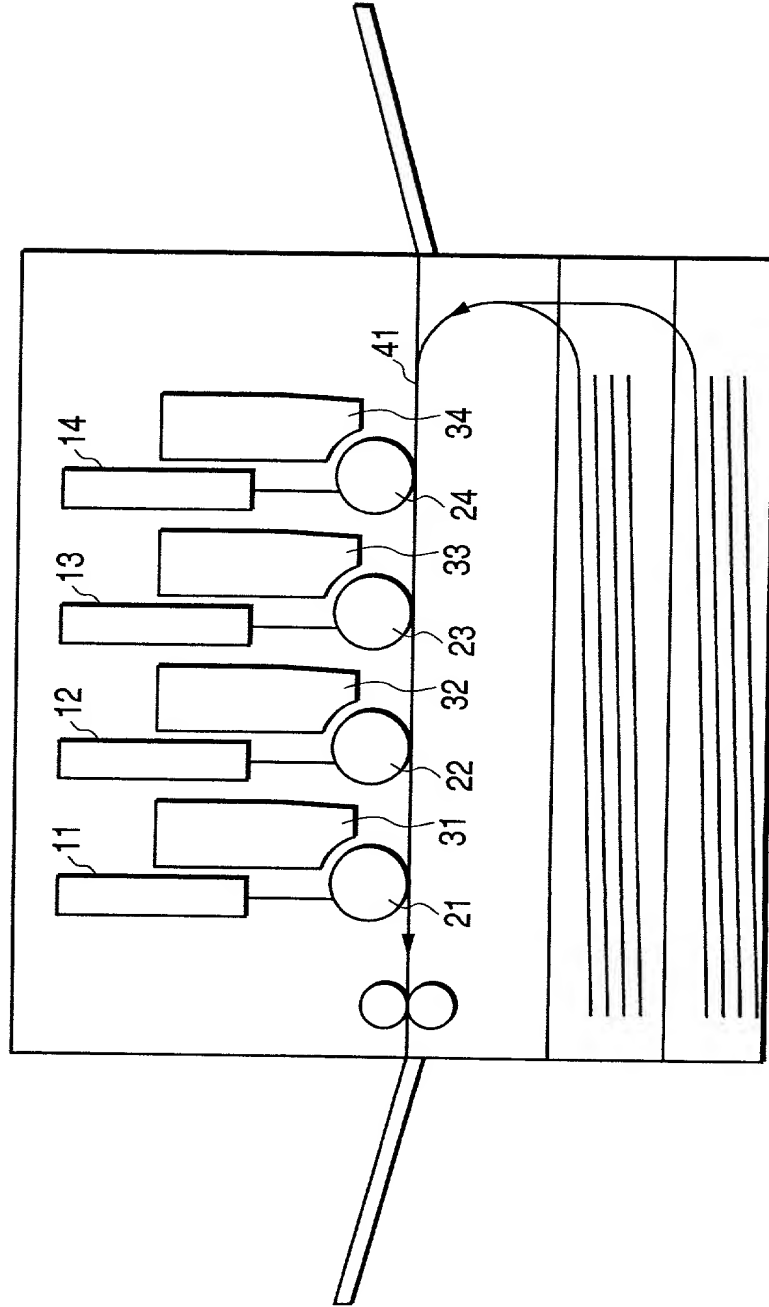
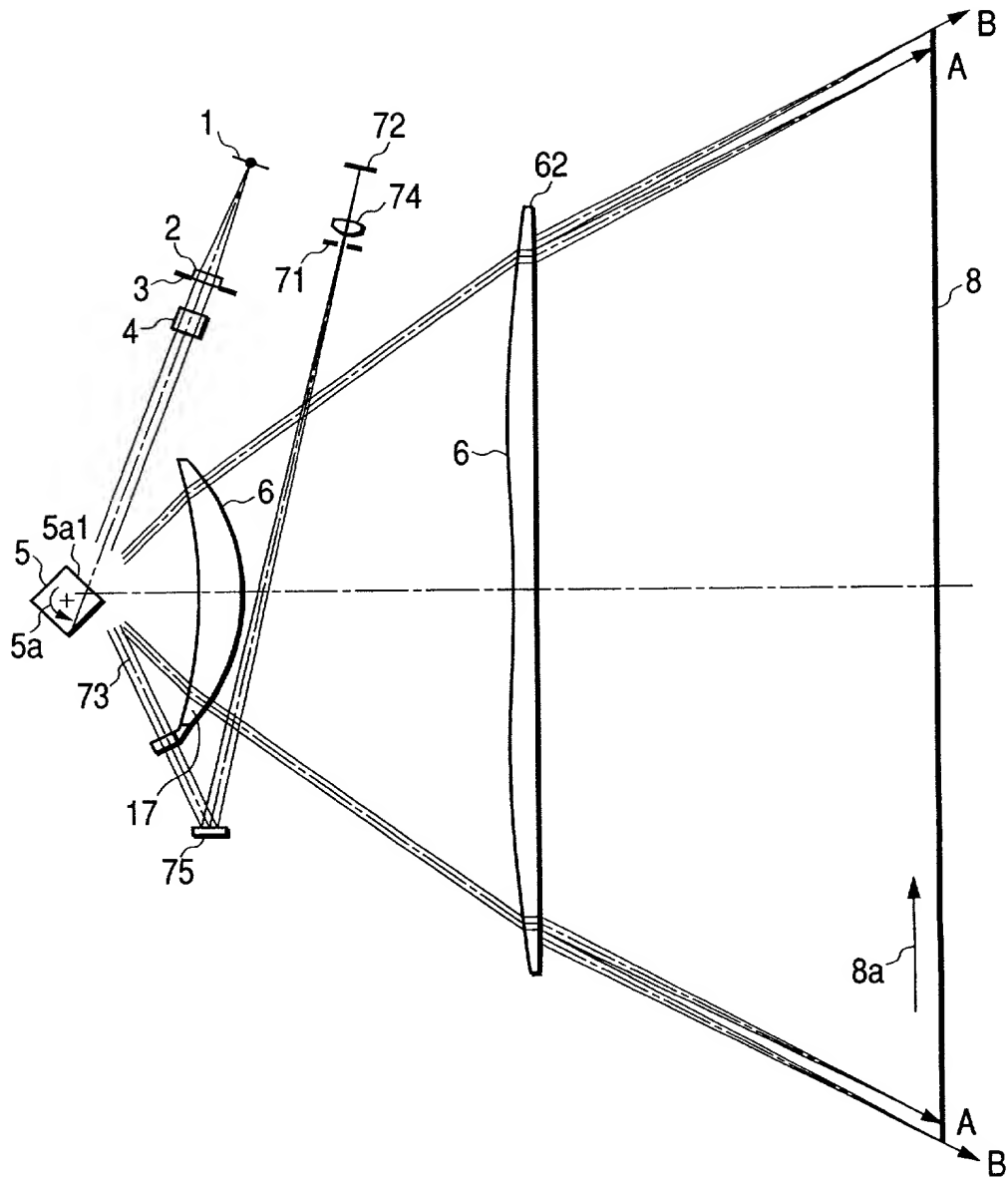




FIG. 9



**COMBINED DECLARATION AND POWER OF ATTORNEY  
FOR PATENT APPLICATION  
(Page 1)**

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled MULTIBEAM SCANNING OPTICAL APPARATUS AND COLOR IMAGE-FORMING APPARATUS

the specification of which ☒ is attached hereto ☐ was filed on \_\_\_\_\_ as United States Application No. or PCT International Application No. \_\_\_\_\_ and was amended on \_\_\_\_\_ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR §1.56.

I hereby claim foreign priority benefits under 35 U.S.C. §119(a)-(d) or §365(b), of any foreign application(s) for patent or inventor's certificate, or § 365(a) of any PCT international application which designates at least one country other than the United States, listed below and have also identified below any foreign application for patent or inventor's certificate, or PCT international application having a filing date before that of the application on which priority is claimed:

Country	Application No.	Filed (Day/Mo./Yr.)	(Yes/No) Priority Claimed
JAPAN	11-066536	12 MARCH 1999	Yes
JAPAN	12-063399	08 MARCH 2000	Yes

I hereby claim the benefit under 35 U.S.C. § 120 of any United States application(s), or § 365(c) of any PCT international application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT international application in the manner provided by the first paragraph of 35 U.S.C. § 112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 C.F.R. § 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application.

Application No.	Filed (Day/Mo./Yr.)	Status (Patented, Pending, Abandoned)
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I hereby appoint the practitioners associated with the firm and Customer Number provided below to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith, and direct that all correspondence be addressed to the address associated with that Customer Number:

**FITZPATRICK, CELLA, HARPER & SCINTO**  
**Customer Number: 05514**

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full Name of Sole or First Inventor Manabu KATO

Inventor's signature \_\_\_\_\_

Date \_\_\_\_\_ Citizen/Subject of Japan

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